




A Tale of a Comet's Tail



*Clues to the
origin of our solar system*



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with

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Granada High School**

Comet McNaught mid-January 2007



Ken Tatebe and Ed Wishnow, Berkeley

Comet McNaught mid-February 2007

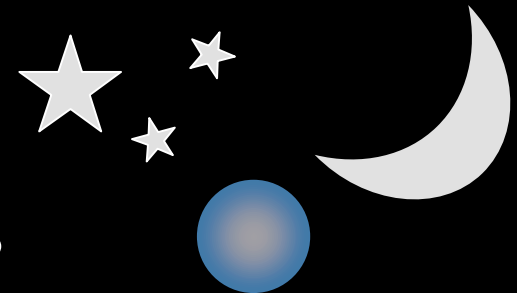


Minoru Yoneta, Queenstown, New Zealand

Imagine you lived 500 years ago....

What objects are “normally” seen in the night sky?

- ✓ moon
- ✓ stars
- ✓ other planets like Venus



How are comets different?

- ✓ tails!
- ✓ harder to predict timing



Halley ~76 years

Hale-Bopp ~2500 years

Historically, comets were **FEARED**



Comet of 1556 & earthquake in Constantinople

Modern Comet Hysteria



Hale-Bopp in 1997

Y2K = end of the world?

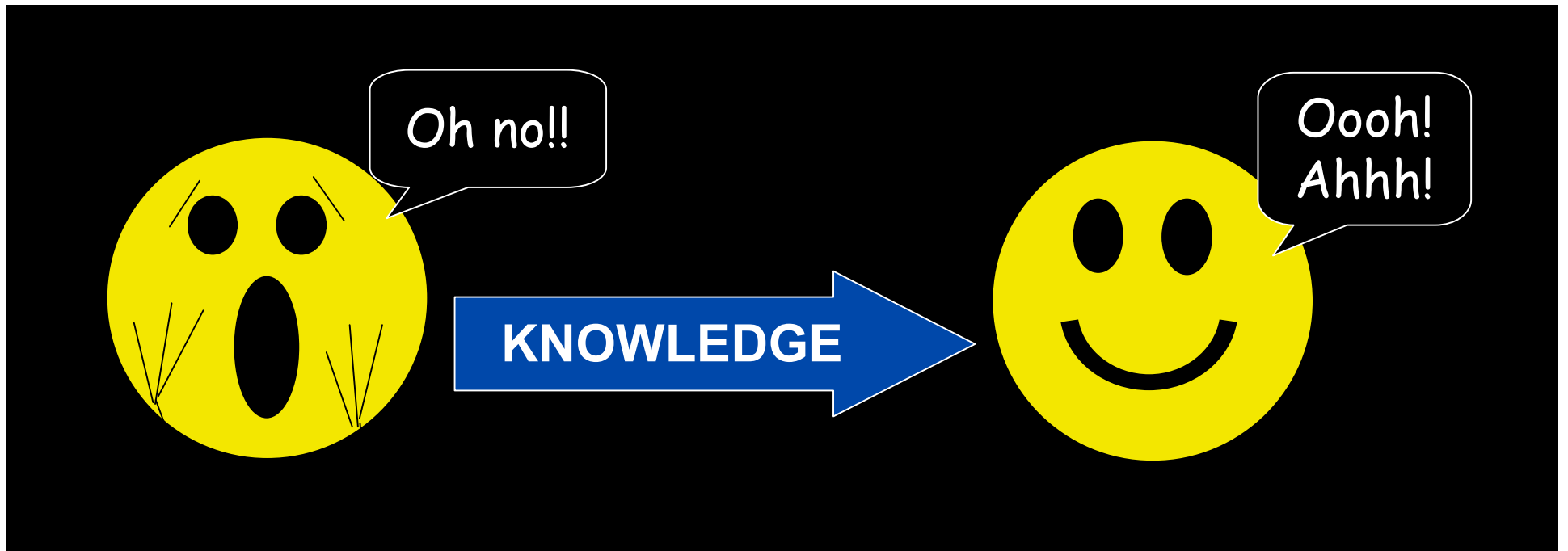


Comet Hale-Bopp will hit
Earth killing us all!



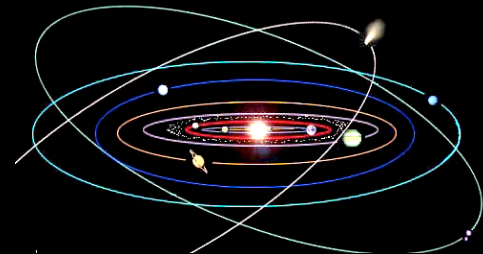
Heaven's Gate cult

✓ On closest approach,
Hale-Bopp was farther from
Earth than the SUN is!



INCREASE your KNOWLEDGE

- 3 basic comet ingredients
- 2 kinds of comet tails
- Where comets formed
- How comets are time capsules
- NASA's Stardust mission
- How comet dust was captured
- What's firing up researchers today



How do Comets Size Up?



7900 miles



2160 miles

CHARON



730 miles

PLUTO



1430 miles

~0.5-10 miles



**COMET
NUCLEUS**

How do Comets Size Up?



7900 miles



CHARON



PLUTO

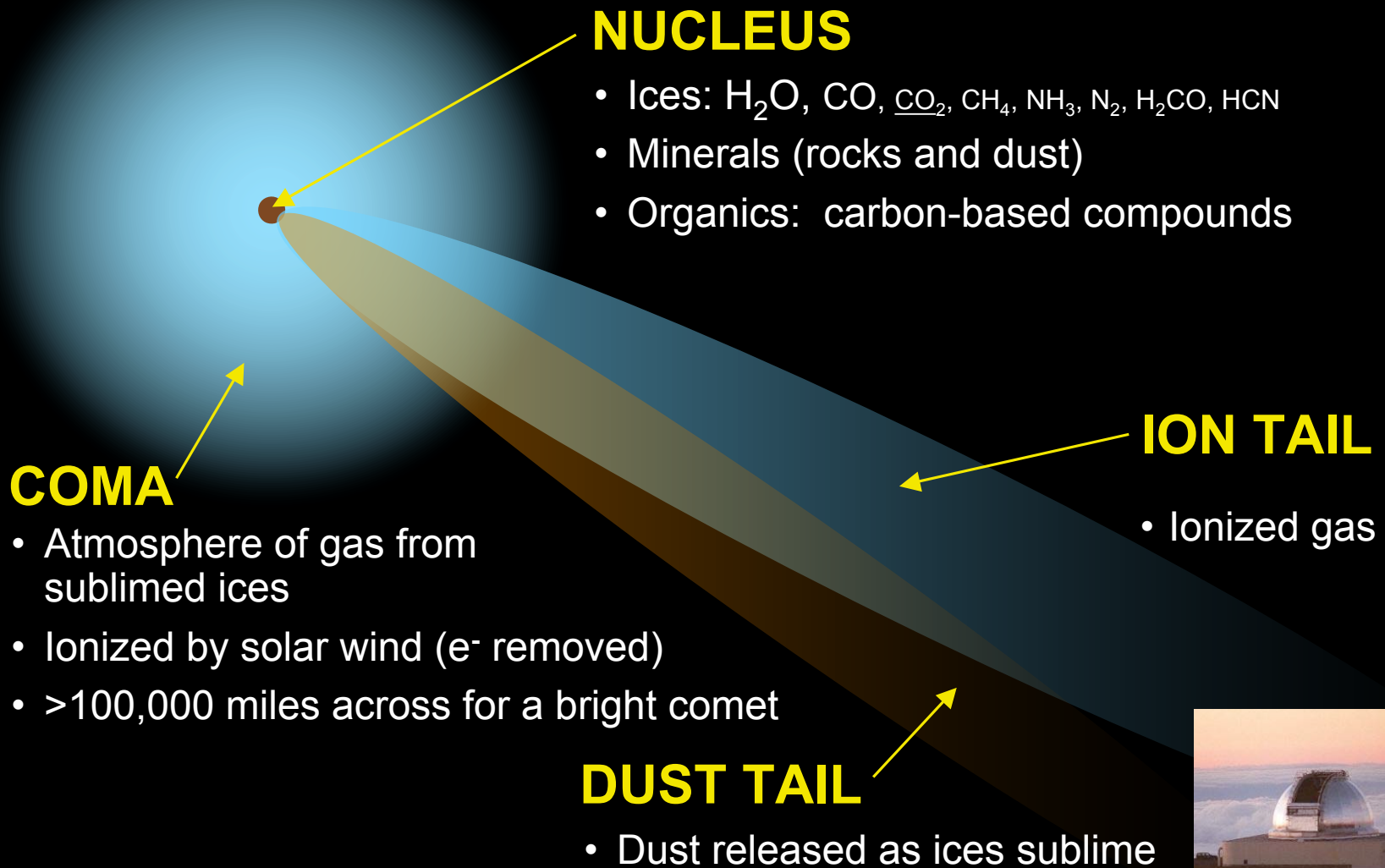


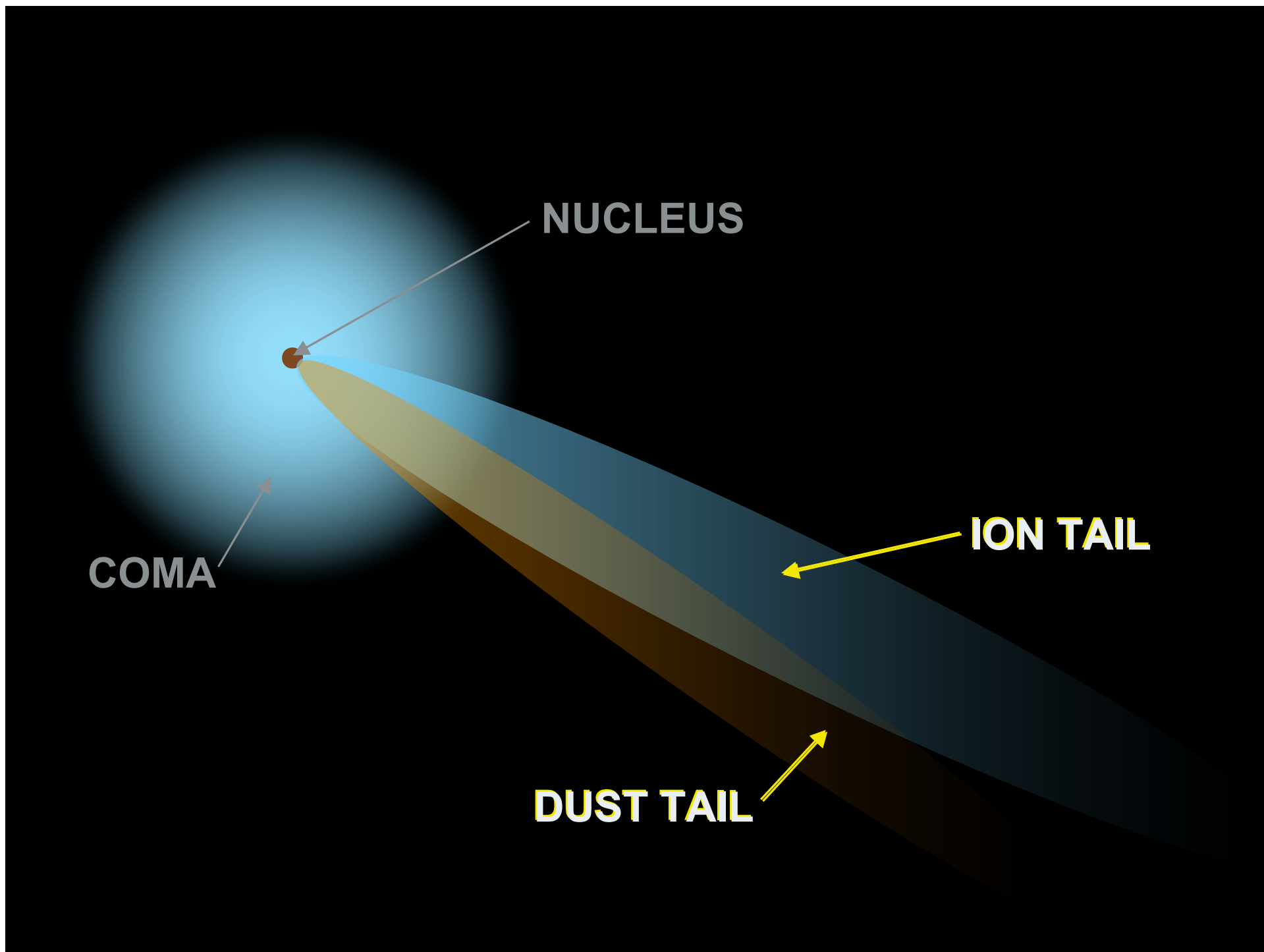
~0.5-10 miles



**COMET
NUCLEUS**

Comet Anatomy





Comet tails within ~7 AU of Sun

ION TAIL

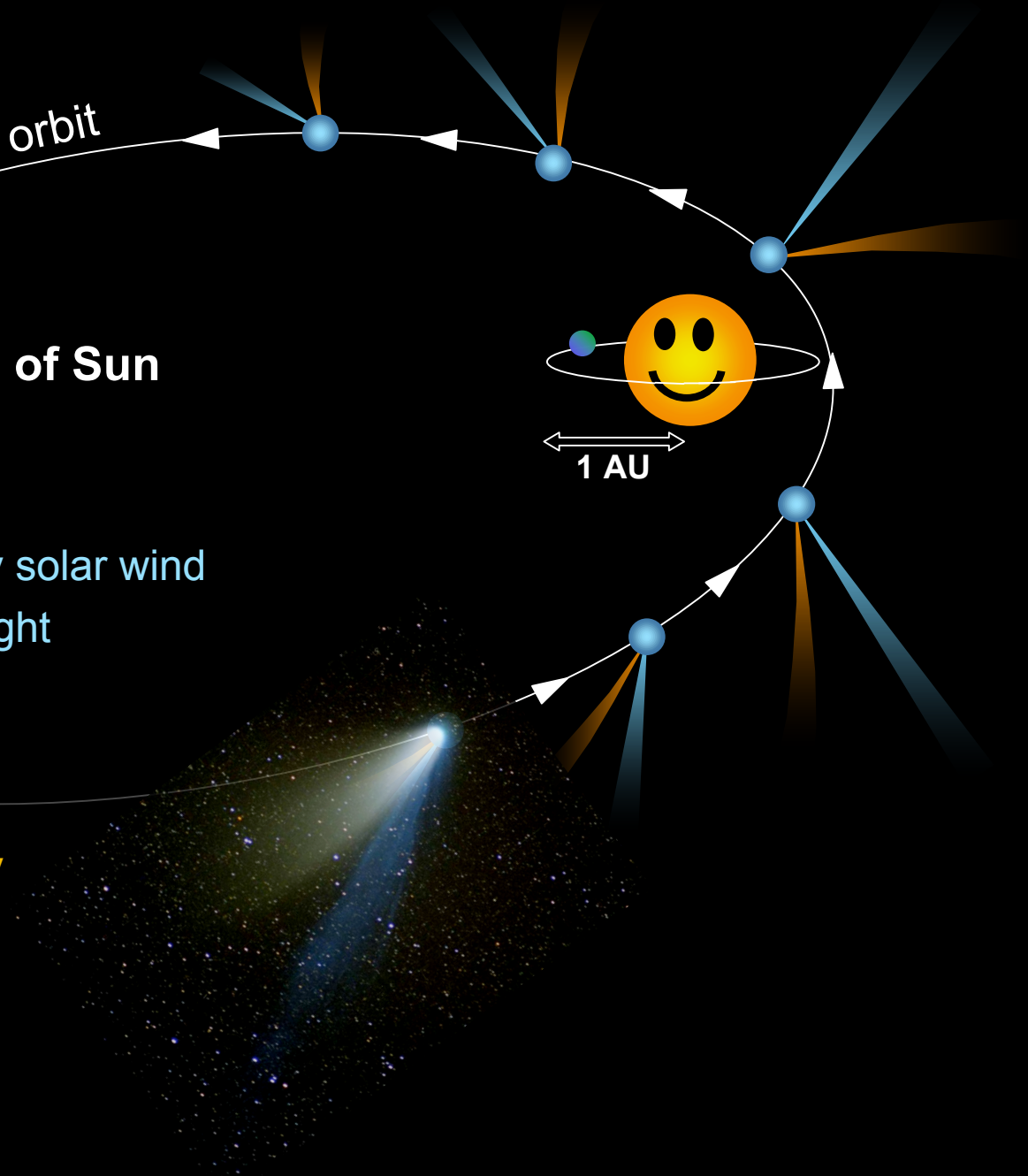
- Pushed away from Sun by solar wind
- Blue: CO^+ scatters blue light

DUST TAIL

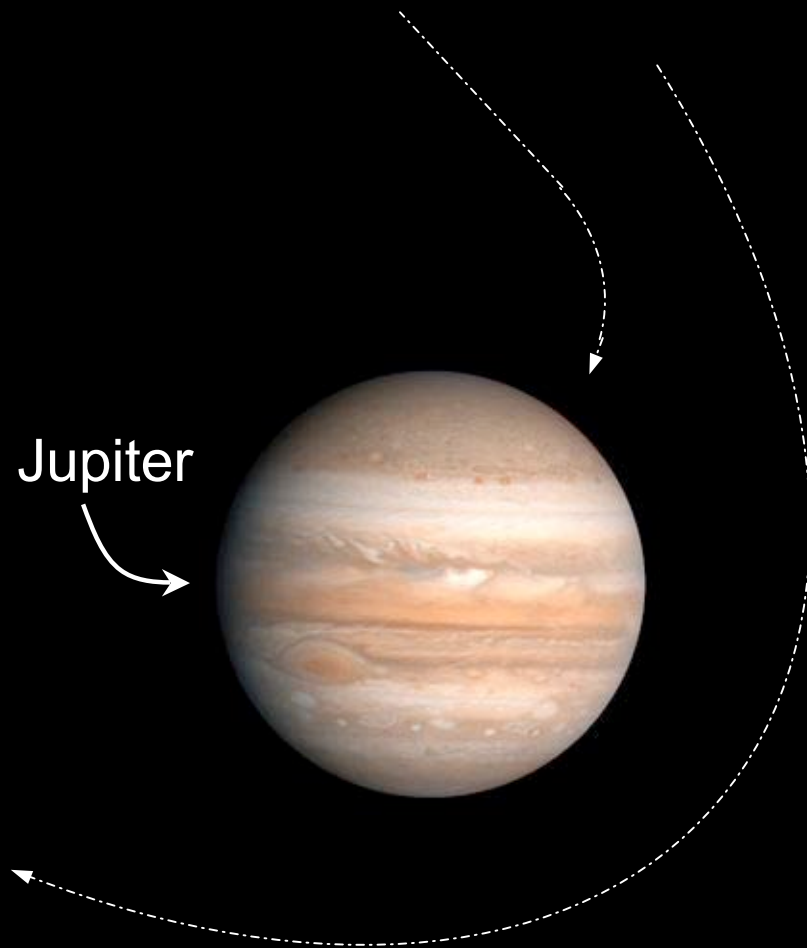
- Pushed away from Sun by radiation pressure
- Dust is heavier: curves back toward comet's path

comet orbit

1 AU



Orbits change by...



GRAVITY of planets



Comet Shoemaker-Levy 1992



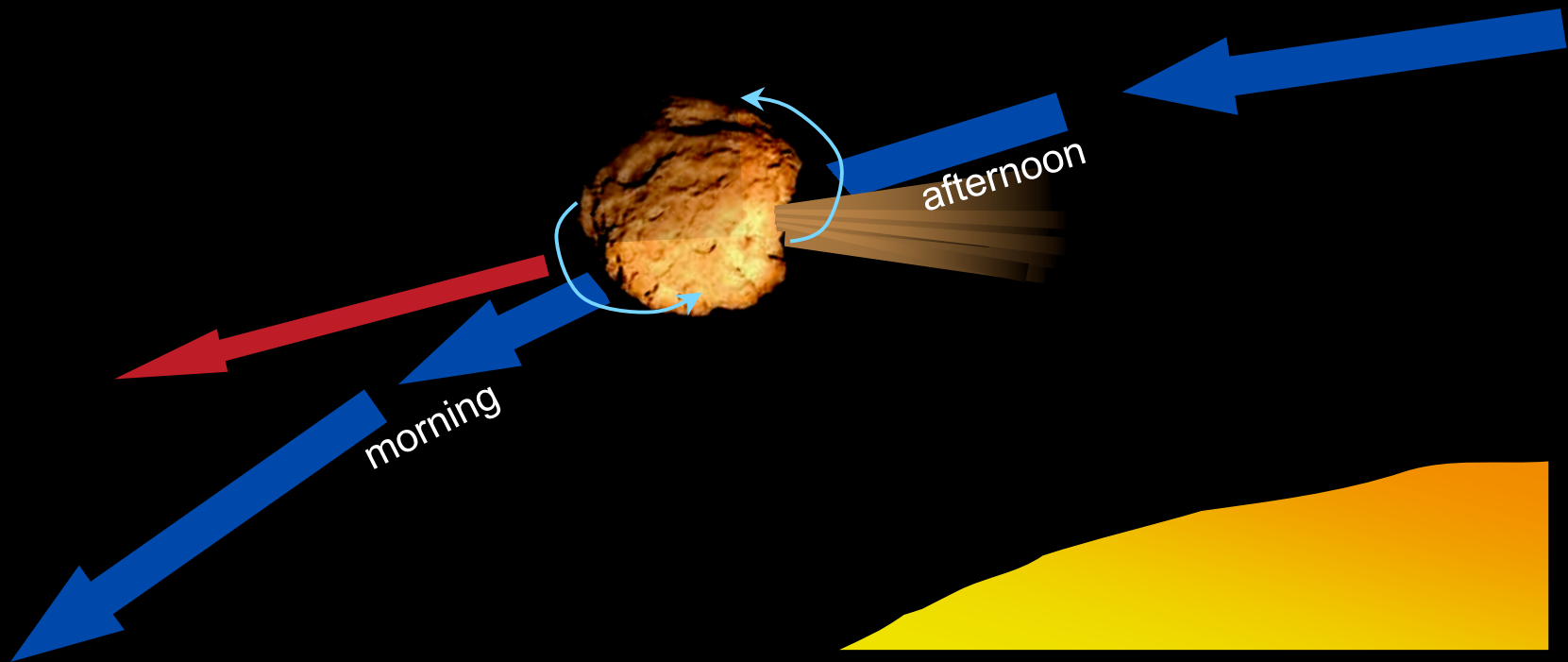
Shoemaker-Levy + Jupiter 1994



1024x1024 Near-Infrared Camera
University of Hawaii 2.2-meter telescope

...and orbits change by... **ROCKET** effects

(Halley was 4 days late in 1910!)



Let's make a comet!

Dish: Comet **Recipe** Prep Time: ~15 min.

2 cups water (H_2O)
2 cups dry ice (CO_2)
Dash ammonia (NH_3)
2 spoons dirt (ROCKS)
Dash of Karo syrup (ORGANICS)

} ICES

Wear work
gloves and
safety glasses!

Line a large plastic mixing bowl with a garbage bag. Mix together water, syrup, ammonia and dirt in mixing bowl with a large wooden spoon. Place 3 garbage bags inside each other, add dry ice and crush with hammer. Add crushed dry ice to bowl while stirring. When mixture is nearly frozen, lift out of bowl using garbage bags and pack together comet like a snowball until firm. Unwrap!

Why do we study comets?

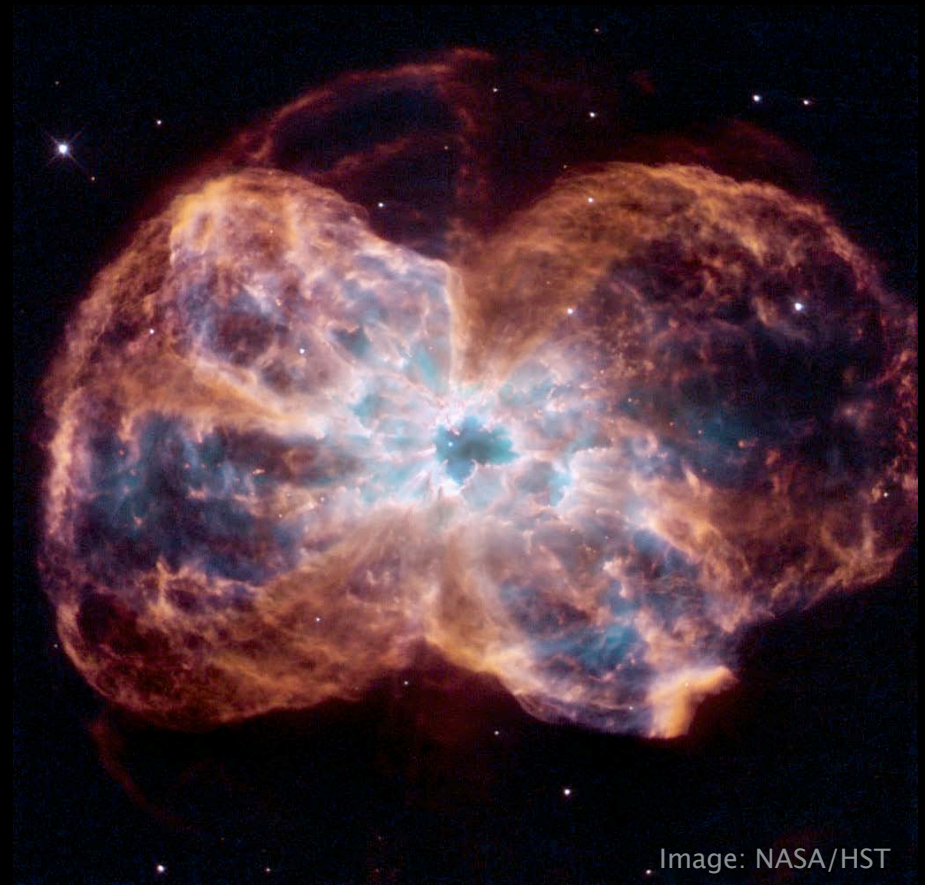
The starting ingredients for our solar system were gas and **STARDUST** ejected by other stars.

stellar recycling program



including us!

NGC 2440, a dying star ejecting gas and dust



Solar System Formation

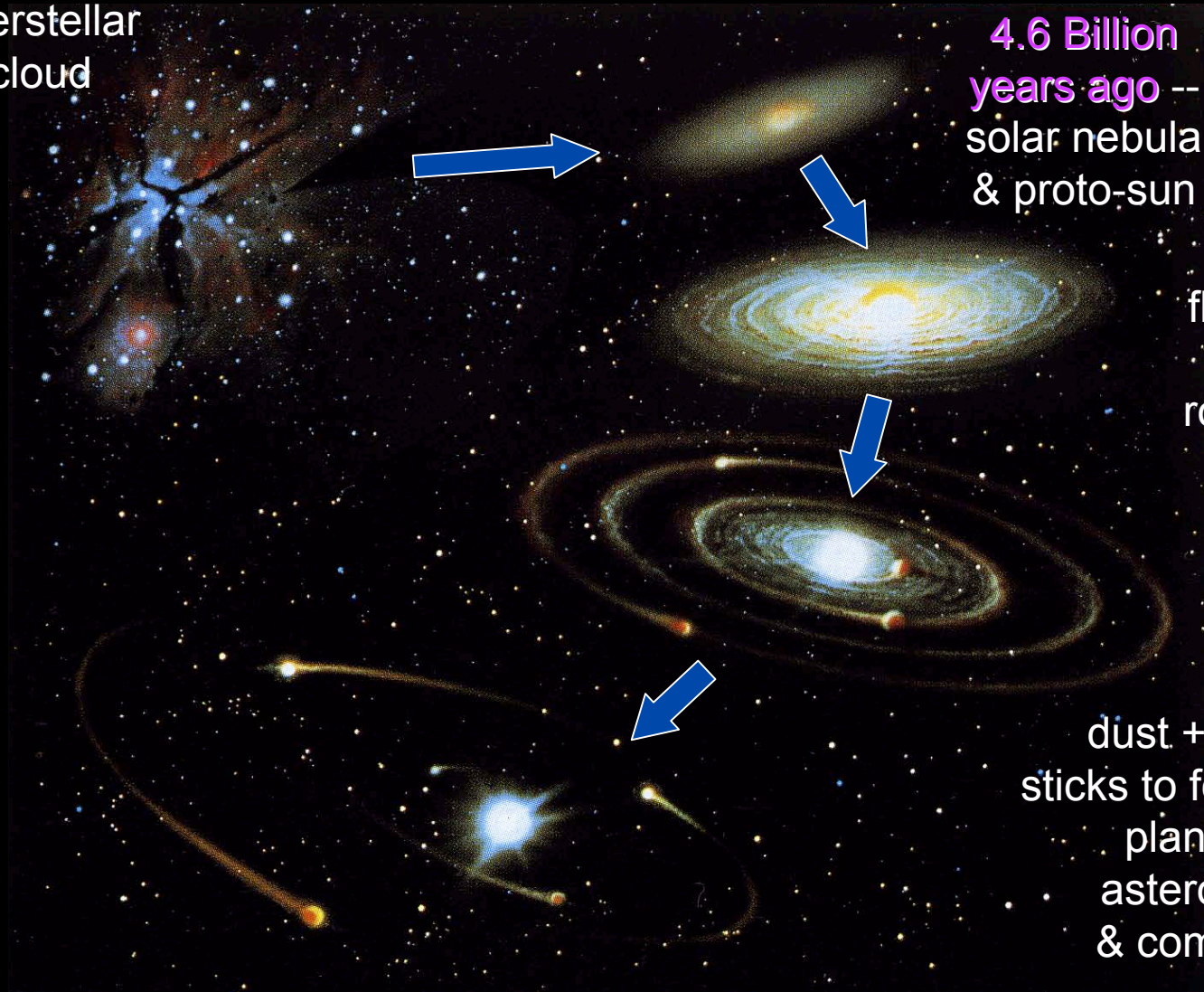
interstellar
cloud

4.6 Billion
years ago --
solar nebula
& proto-sun

flattens
into a
rotating
disk

dust + gas
sticks to form
planets,
asteroids
& comets

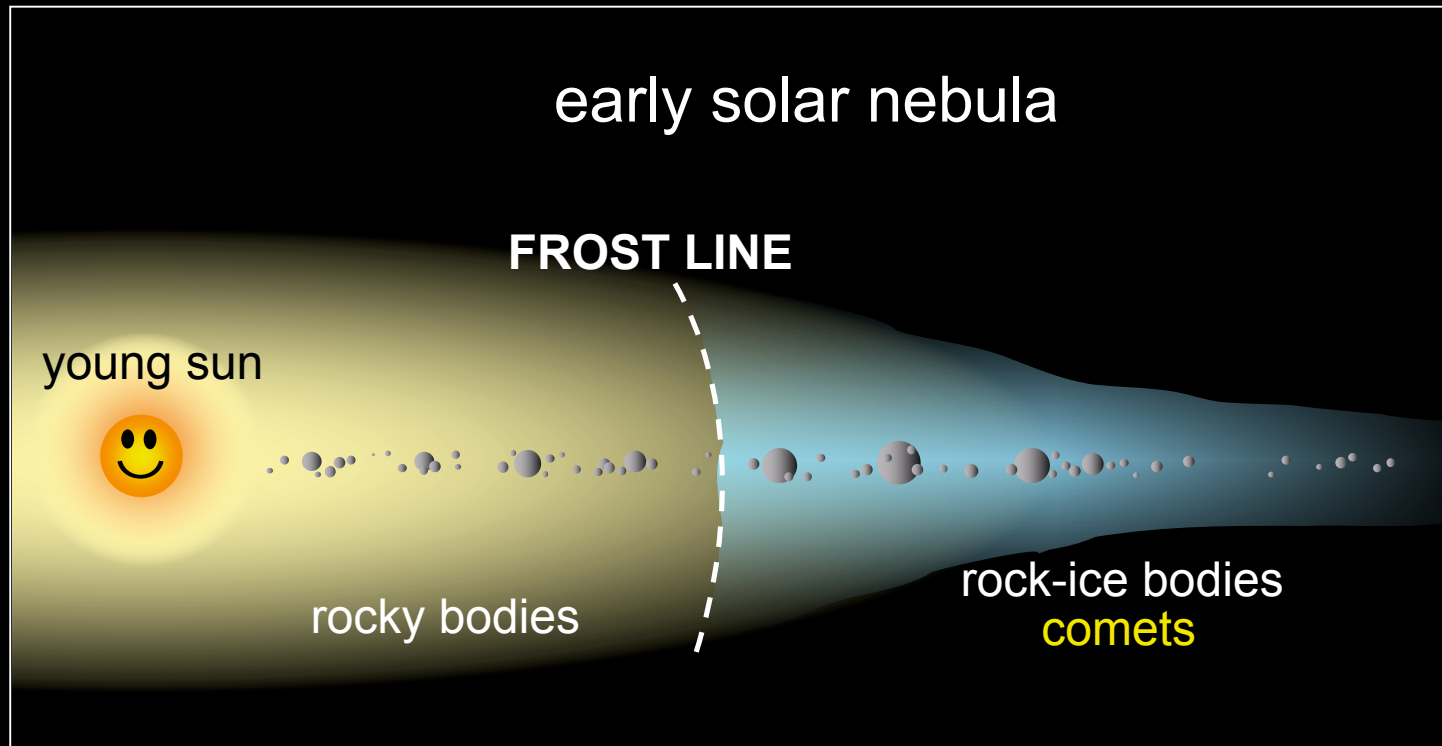
painting by Kazuaki Iwasaki



HOT



COLD



*Comets hold starting ingredients for planets...
including **STARDUST!***

Comets = Frozen Time Capsules

Meteor Crater in AZ



- Today, Earth's atmosphere protects from most impacts
- Early Earth bombarded by comets, asteroids
- Chicxulub Crater → dead dinosaurs 65M years ago?



H_2O
 CHON *Building blocks for life,
water & primitive organic matter,
from comet bombardment?*



Comets delivered basis for LIFE?

Mission to a Comet: *STARDUST*

- *1st sample return from a known comet for detailed study on Earth*
- NASA Discovery Class Mission <\$300M
- 1st U.S. solid sample return since Apollo 17 in 1972
- Record 3 billion miles total distance for a solar-powered spacecraft
- Record 2.72 AU from Earth

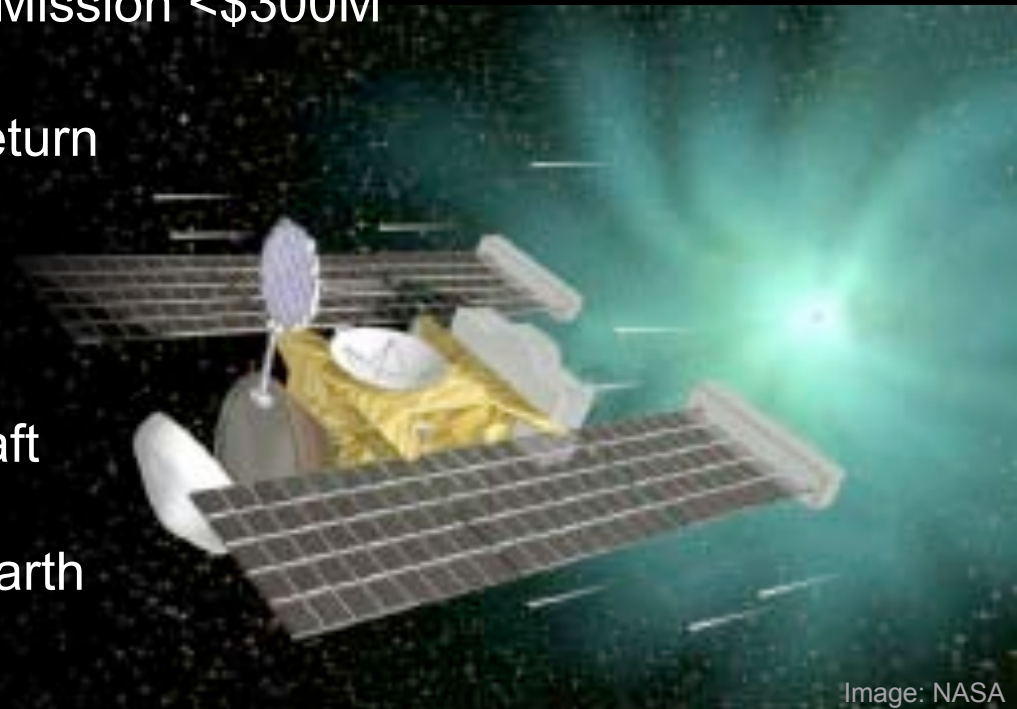


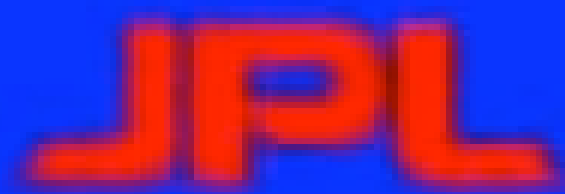
Image: NASA

Stardust Launch



February 17, 1999

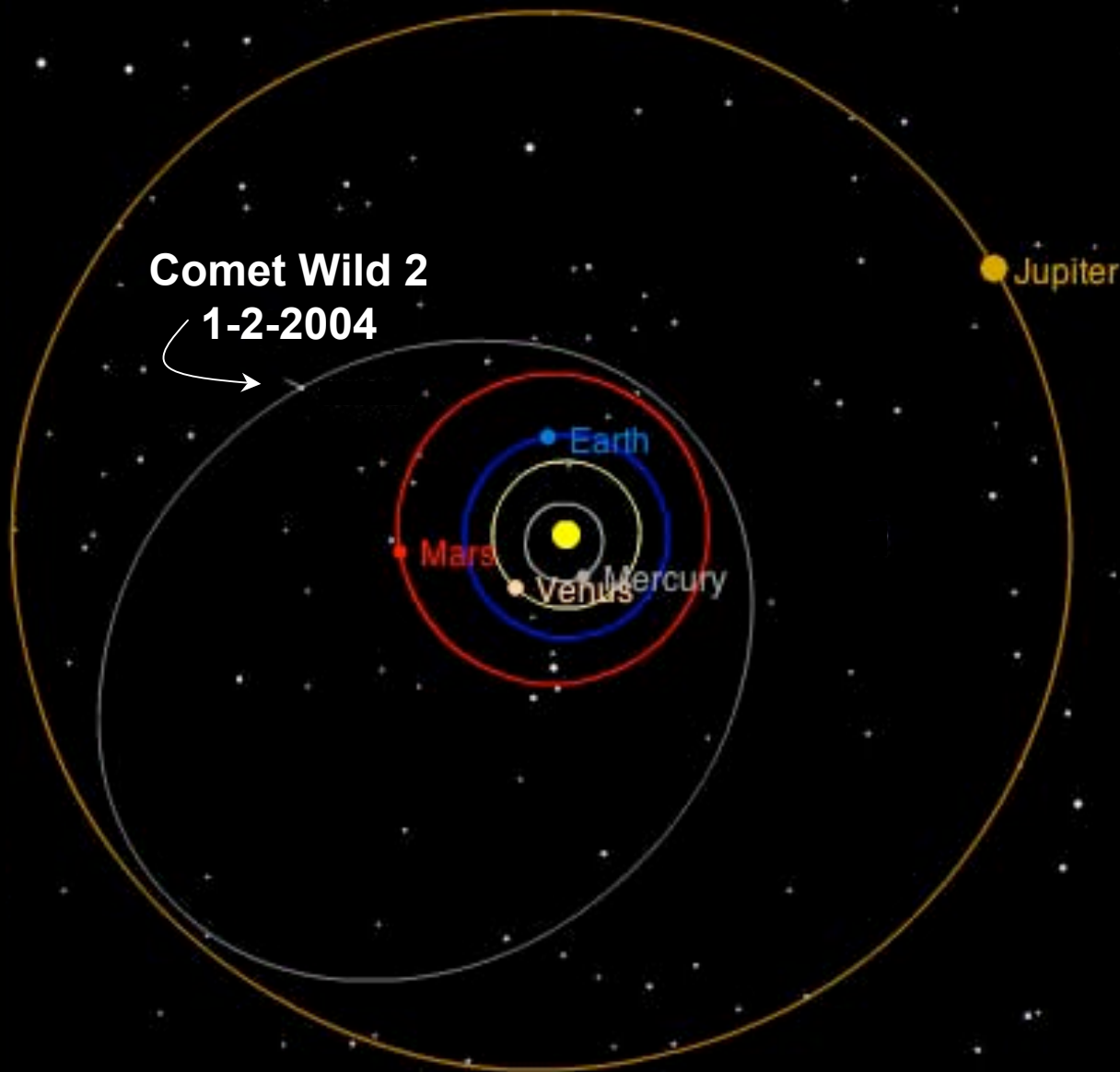




Stardust Launch
7 February, 1999

AVC-1999-023

Encounter: Lucky Comet Wild 2



Deflected in **1974**
by Jupiter's gravity



inner solar system
orbit

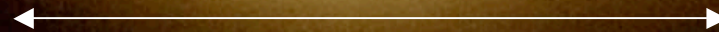
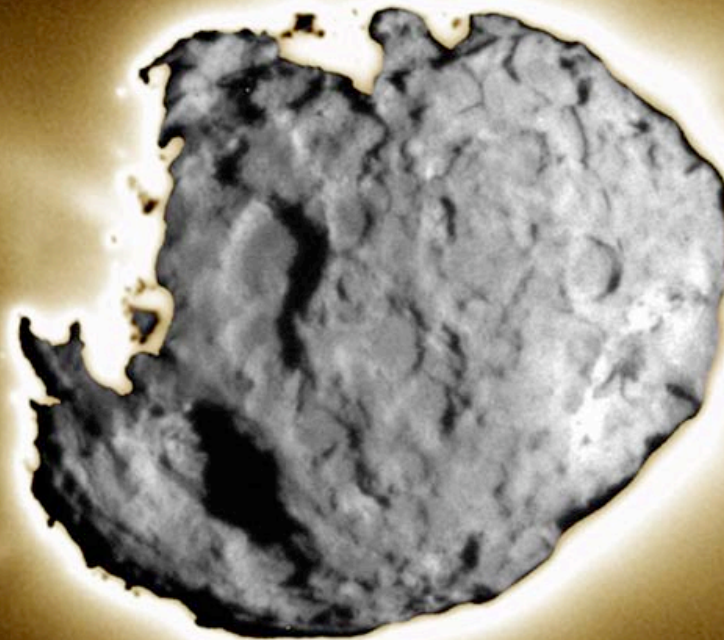
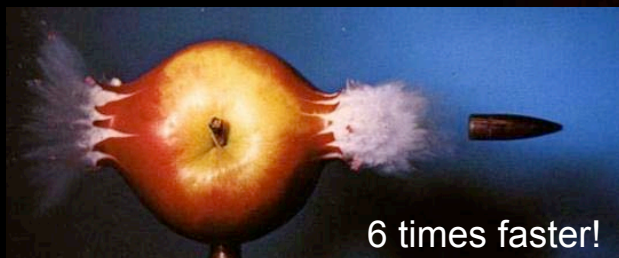
→ Intercept 1.86 AU

→ Wild 2 circled sun
only 5x -- fresh!

Wild 2 up close and personal



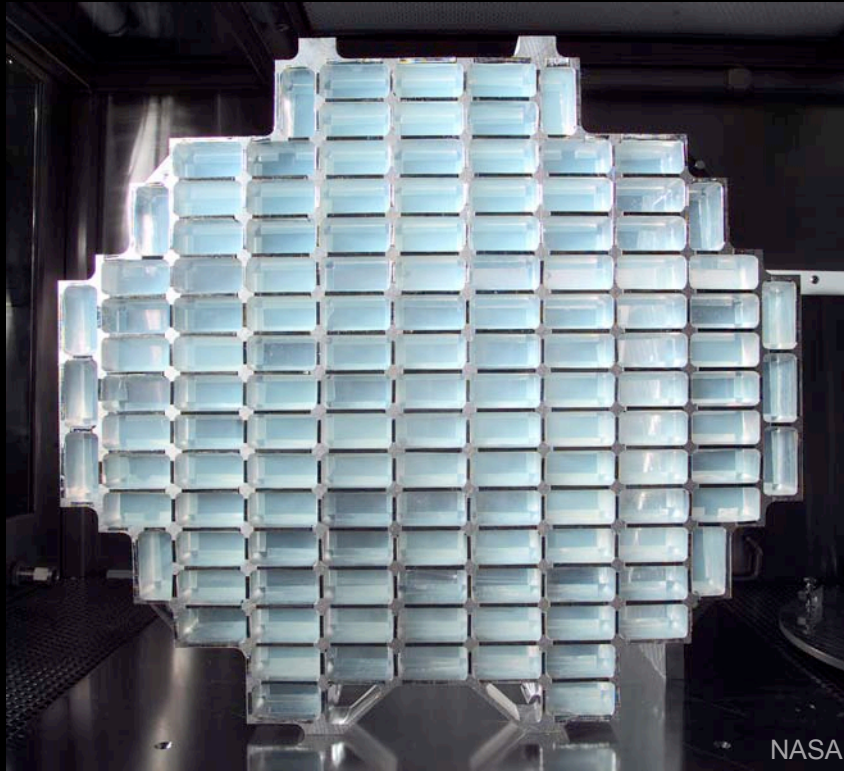
<150 miles of nucleus
@
~13,700 miles / hour
relative speed



~3 miles

Images: (top left) NASA, (bottom left) Harold Eggerton, (right) NASA/JPL

AEROGEL: Catching comet dust



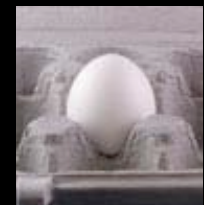
Ultra-low density glass foam

world's lightest solid

- ✓ strong
- ✓ transparent
- ✓ 99.8% holes
- ✓ 5 mg/mL

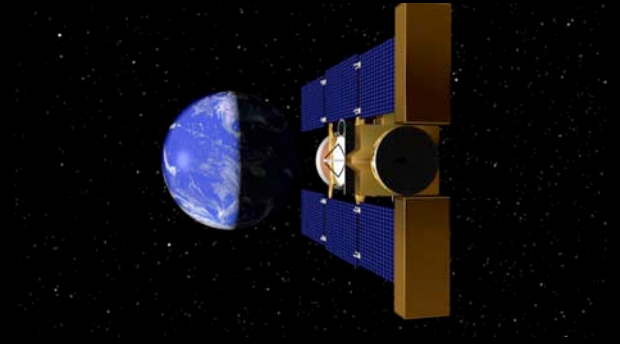


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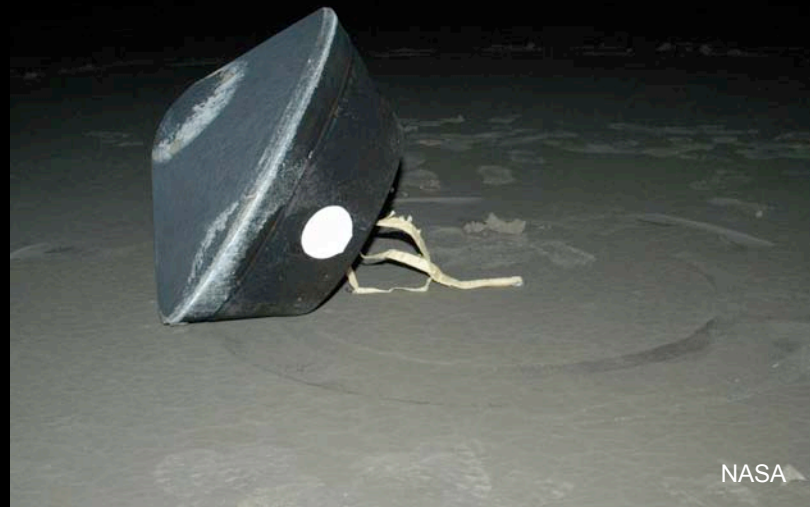
Dust particles slow down g r a d u a l l y

Stardust Returns



January 15, 2006

*Utah desert
28,000 mph*

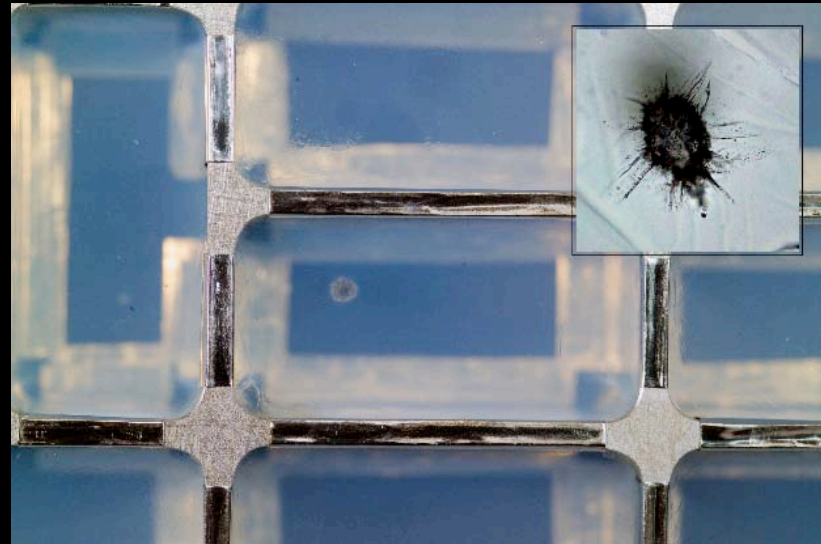


The image shows the title card for 'The Daily Show with Jon Stewart'. The text is centered and features a blue-to-white gradient. The background is a dark studio with blue lighting, including a large screen on the left showing a cityscape and a smaller screen on the right showing a person. The floor has a circular pattern of light and dark segments.

THE DAILYSHOW

WITH JON STEWART

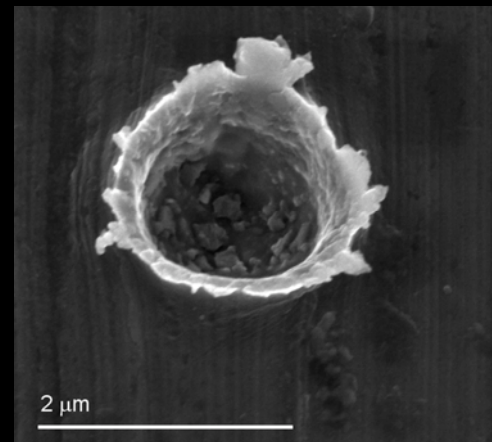
“Wild” Times Studying Stardust



more than 150



Images: (top left) Ishii, (others) NASA/Stardust PET



Spain and Australia

researchers from United States, France, Japan, Italy, U.K., Germany,

Tiny Samples!

comet particle 
5 microns

Total sample return

< 1 mg



ant
3-20 mg

**HOW CAN WE
STUDY SUCH
TINY OBJECTS?**

human hair

100 microns = $\frac{1}{10}$ mm



Powerful X-rays

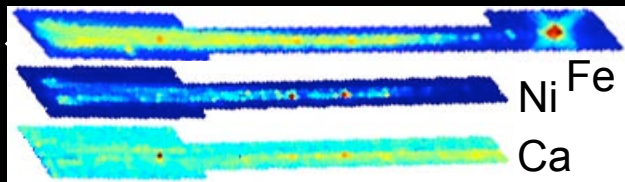
Track Chemical Maps

Microscope image



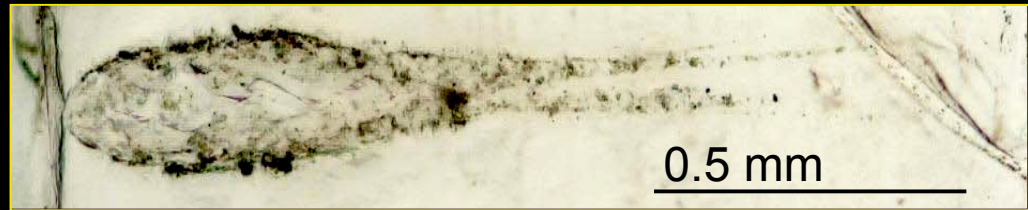
4 mm

X-ray chemical maps



Track Shapes

Microscope image



Powerful X-rays

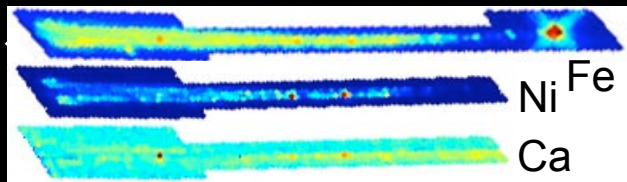
Track Chemical Maps

Microscope image



4 mm

X-ray chemical maps

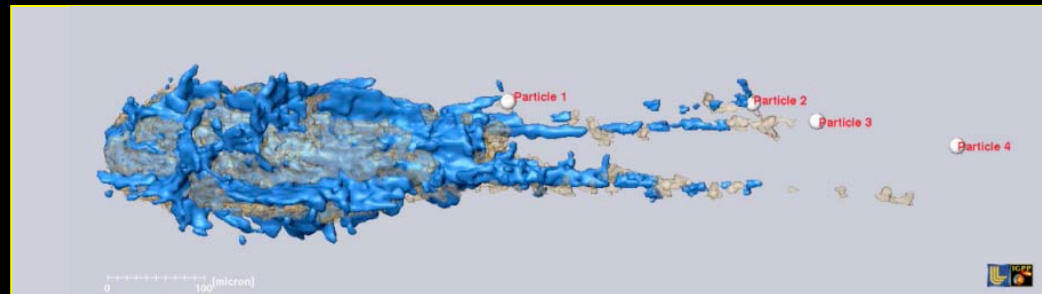


Track Shapes

Microscope image

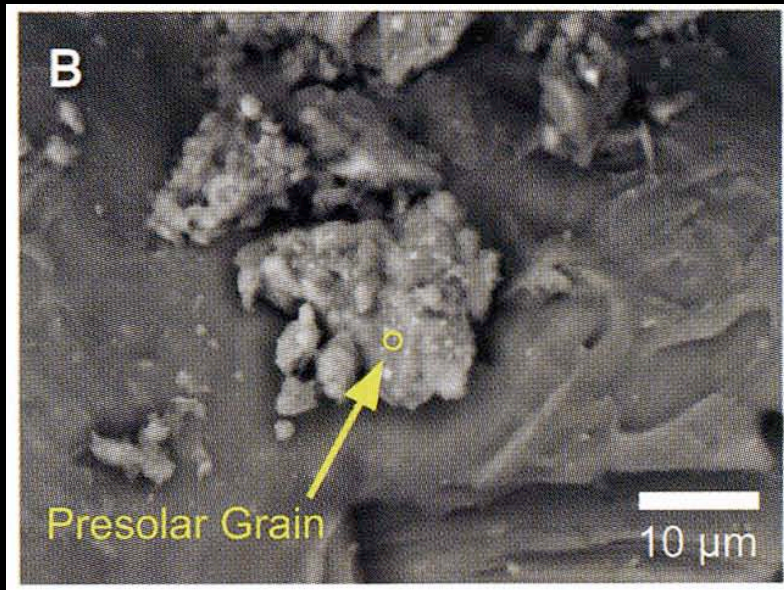


Shape reconstruction by X-ray tomography



Images: SSRL/LLNL/Stardust Preliminary Examination Team/ NASA

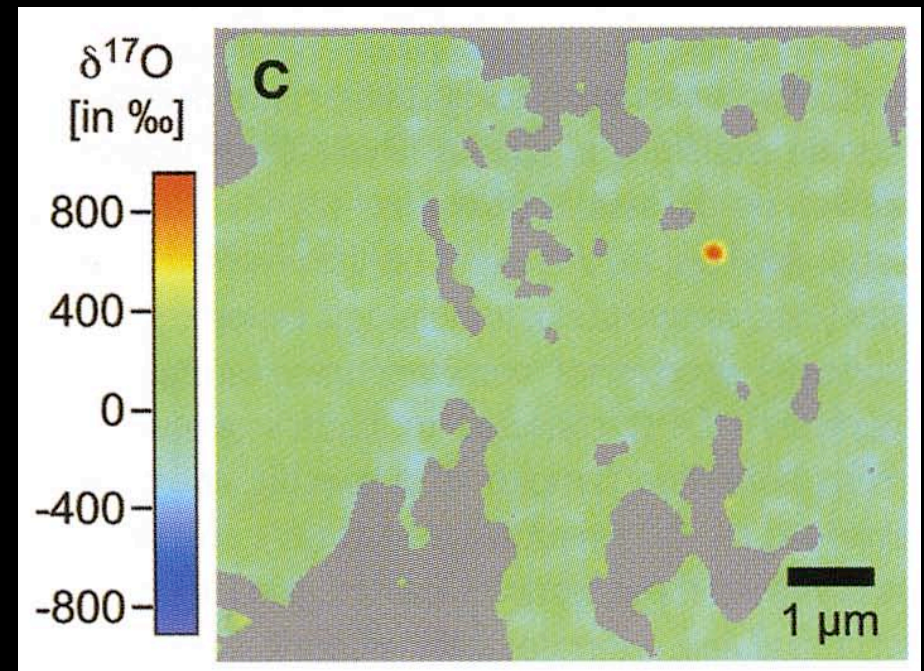
Ion Microscopes



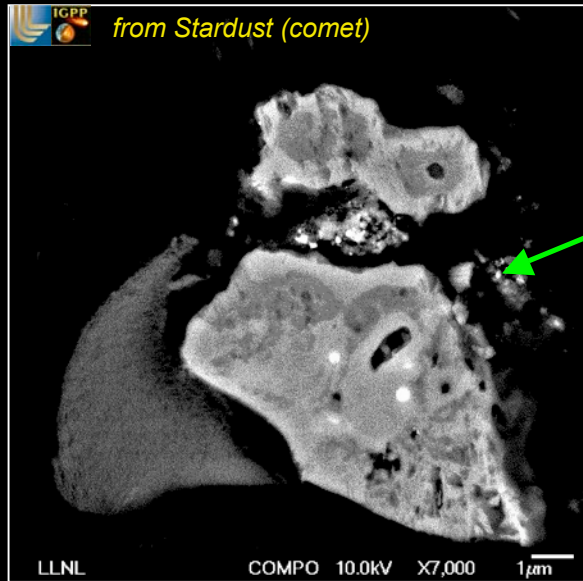
Images: McKeegan et al, *Science* 314, 1724.

a few grains of
stardust in Stardust comet dust

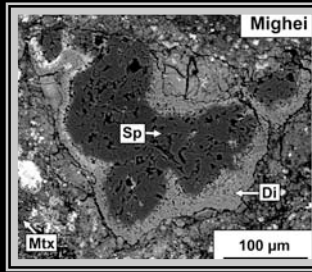
Isotope maps



Electron Microscopes

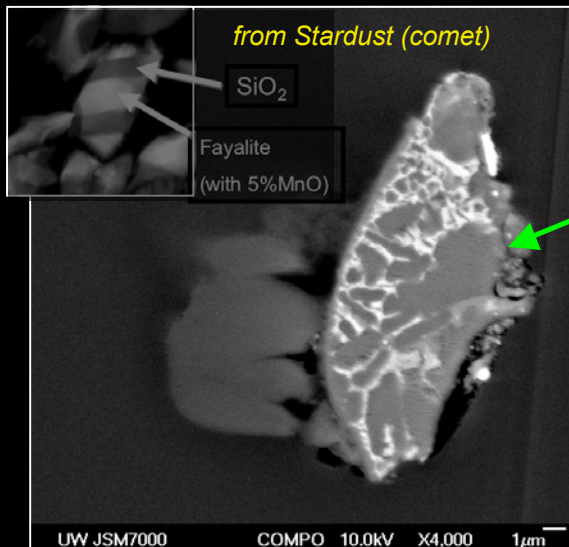


from a meteorite

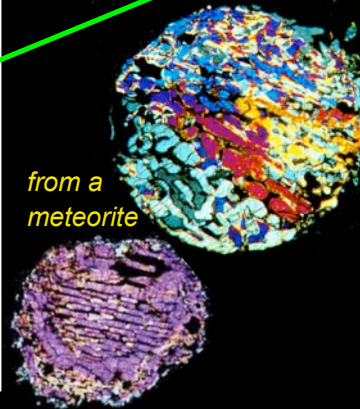


**CAIs: rocks formed
CLOSE to Sun!**

Oldest known SS objects



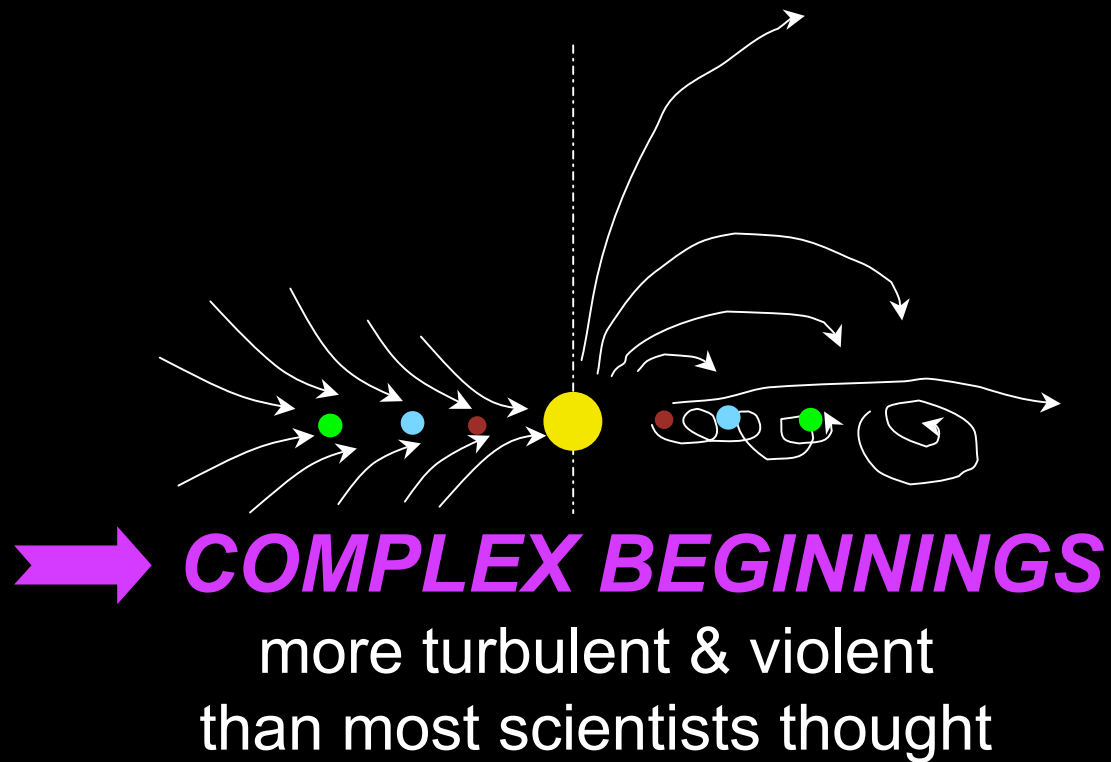
from a
meteorite



**Chondrules: rocks formed
CLOSE to Sun**

... but what does it all MEAN?

some stardust but also
HOT rocks in the
solar system's **DEEP FREEZE!**



The Great Comet of 2008

The End